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COMPUTER DRIVEN ELECTROLUMINESCENT VERTICAL SCALE INDICATOR

by James A. Pellegrino and Jules L. Rosenbaum

Prepared by
AEROSPACE PRODUCTS RESEARCH CORPORATION
Santa Monica, Calif.
for Ames Research Center

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COMPUTER DRIVEN ELECTROLUMINESCENT

VERTICAL SCALE INDICATOR

By James A. Pellegrino
and Jules L. Rosenbaum

SUMMARY

Essentially this report outlines the effort expended in the design, development, and fabrication of two types of solid-state digitally controlled electroluminescent (EL) vertical scale indicators. Both types of indicators were delivered to NASA Ames Research Center, for evaluation under laboratory simulated environmental conditions. One type is a Single Parameter Indicator which employs one bargraph, with scale and parameter indication; and the other is a Flight Director which uses two adjacent bargraphs, with scale and parameter indication.

As indicated in the report, the delivered indicators met all of the following specification requirements: Fast dynamic response compatible with the SDS 920 Computer update-time capability of one to twenty milliseconds; automatic lamp brightness regulation; absence of glow, flicker, and cross-coupling in the lighted display; use of high-contrast display techniques; interchangeability and versatility compatible with an instrument used in laboratory simulations; multicolor display capability; internal information storage; low power consumption, capable of operating at 2.5 watts.

The objectives for simulator environments were met with the exception of temperature. The initial objective of 0°C to 100°C was found to be no problem with the electronics; however, further development of the EL lamps and the photoconductor brightness sensor are required in order to eliminate degradation. Temperatures in excess of +85°C permanently degrade present photoconductors and also the EL phosphors.

Some difficulty was encountered in isolating problems which appeared under dynamic operation of the instruments. These problems were isolated to intermittent solder joints and marginal components which can be expected due to the complexity involved with interchangeable modules and handling of items during the de-bug phases. There was no evidence of glow or flickering of unlighted or lighted segments at normal operating rates. The successful operation of special glow elimination circuitry and the brightness regulator under dynamic conditions was most encouraging.

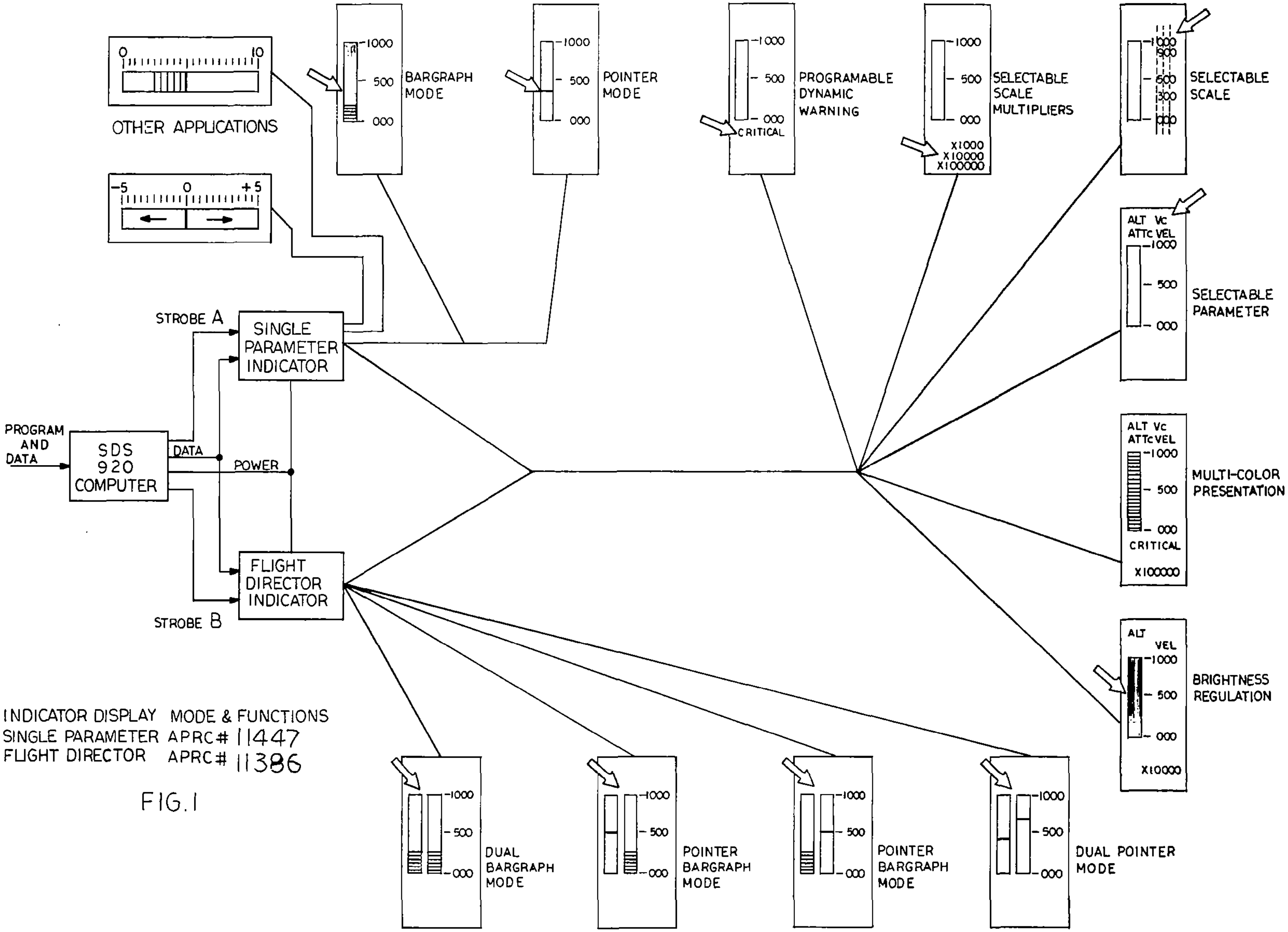
INTRODUCTION

The development of a computer driven vertical scale indicator utilizing electroluminescent lamps to visually display the input data was accomplished by the use of advanced state-of-the art techniques. The indicator device mechanization selection was based upon test results obtained by the design and construction of a functioning breadboard during Phase I of the program. Trade-off studies were used until a final configuration was found which could best provide the indicator requirements. Figure 1 illustrates the delivered indicator's display modes and functions.

All of the primary design requirements have been successfully met. The first of these requirements being a dynamic response which is compatible with the SDS 920 computer update-time capability of one to twenty milliseconds. Automatic lamp brightness is achieved through the use of a variable frequency, controlled-amplitude power source for the EL lamps. By the use of special circuitry, glow, flicker, and cross-coupling are eliminated in the lighted display. Contrast enhancement is provided throught the use of a circular polarizer, a high efficiency antireflective coating and a neutral density light transmission filter. Interchangeability and versatility compatible with an instrument used in laboratory simulations at Ames Research Center are achieved by the use of five interchangeable module types and plug-in lamps. Multicolor display capability is achieved through the use of four phosphor types. Yellow, white, blue and green colors were provided for the four different lamp types: Bargraph, Scale Multiplier, Scale Background and Parameter. Internal information storage is gained through the use of Micro-circuit Logic Elements. Low power consumption, capable of operating at 2.5 watts is achieved through the use of a unique high voltage logic design scheme scheme.

The indicator mechanization technique selected utilizes Diode Transistor Logic (DTL) microcircuitry for internal data storage and decoding, high voltage transistor and silicon controlled switch circuits for high voltage switching, and state-of-the-art electroluminescent lamps for the display of information. This program employed a high voltage logic matrix technique to allow the use of available and proven control circuitry.

The objectives of this effort were those associated with the development of a space quality solid-state indicator. Low power performance and functional flexibility were of prime importance for the intended simulator evaluation of the indicator's capabilities. These objectives were met through the use of five interchangeable module types, interchangeable plug-in EL lamps of four different colors and special circuitry to minimize power consumption.



INDICATOR DISPLAY MODE & FUNCTIONS
SINGLE PARAMETER APRC# 11447
FLIGHT DIRECTOR APRC# 11386

FIG. 1

A brightness regulation system was developed to automatically compensate for the EL brightness degradation phenomenon and it was found to have excellent results since it provided both long time and short time regulation.

The unusually low power consumption objective of 2.5 watts was accomplished by utilizing high efficienty green EL lamps operating at approximately 15 foot-lamberts, reducing the logic voltage from 5V to 4V. The reduction of power dissipation in the brightness regulator was achieved by reduction of the EL drive voltage from 22V to 13V and near saturation of the regulator.

In order to allow the brightness regulator to regulate at any desired set brightness level from 0.5 foot-lambert to 20 foot-lamberts and to regulate for the four different colored lamps the normal operating power is 3.5 to 4 watts.

Development

Of the many development hurdles encountered during the program one of the most annoying was the mask. In order to reduce the parallax, a thin photographic mask of approximately .007 inch thickness was initially used. Although it did minimize the parallax its mechanical stability left much to be desired. Attempts to support this thin mask with a .030 inch thick clear plastic overlay did not prevent enough warpage to allow the mask to lie flat against the EL lamps. The final mask utilized was a .060 inch acrylic plastic rear silk-screened. Unfortunately a pliable plastic could not be used since it melted during the silk-screen paint-baking process. Attempts to use unbaked paint provided a marginal homogeneous paint surface. Attempts to camouflage unlighted numbers and characters were found to be limited by an inability to exactly match the reflectance of the EL lamp to the mask black paint. The use of the circular polarized filter does, however, minimize this effect.

The successful fabrication of the EL lamps required did not turn out to be a small task. Due to the high resolution requirement of thirty-two (32) segments per inch on the bargraph lamps the initial yield rate was about 10%. Subsequent investigation showed that the EL lamps required a voltage forming process much like capacitors. This forming process requires a minimum energized time of five hours. Without the forming, the sudden application of full voltage to the EL lamps will cause one or more punctures of the phosphor dielectric and a subsequent non-catastrophic blackburn spot. Initial contact techniques resulted in minor "spotting" of the EL lamp due to the contact effects upon the reflectance of the rear layer. The use of an improved fabrication process plus compatible contact materials eliminated this effect. Lamp construction difficulties were also encountered due to the environmental requirements. Due to initial limitations caused by epoxy encapsulation materials the lamps sustained permanent damage at temperatures below $40^{\circ}F$. Attempts to match the temperature coefficient of the phosphor coated substrate proved futile with normal techniques of filling, etc. This difficulty was resolved through the development of a compatible encapsulating material of the Urethane family. Lamps fabricated by these final techniques are capable of operating at temperatures as low as $-65^{\circ}F$.

Theory of Operation

The SDS computer sends a data word of 13 bits and a data strobe. The data strobe allows the data stored in the scale and buffer modules to be set as required. The buffer module provides stored data to the enable and units modules which decode and provide control inputs to the high voltage matrix. The enable module also provides decoding for the hold module. The high voltage matrix assembly provides the logic required to convert the sixteen (16) units drivers and the eight (8) enable-hold drivers into a 128 segment display. For bargraph generation each of the eight (8) groups are enabled in sequence while the sixteen (16) units functions are used for each group. When each new group is enabled the last group is held "ON" by the hold function. For pointer generation each group is enabled individually and the hold function is not used.

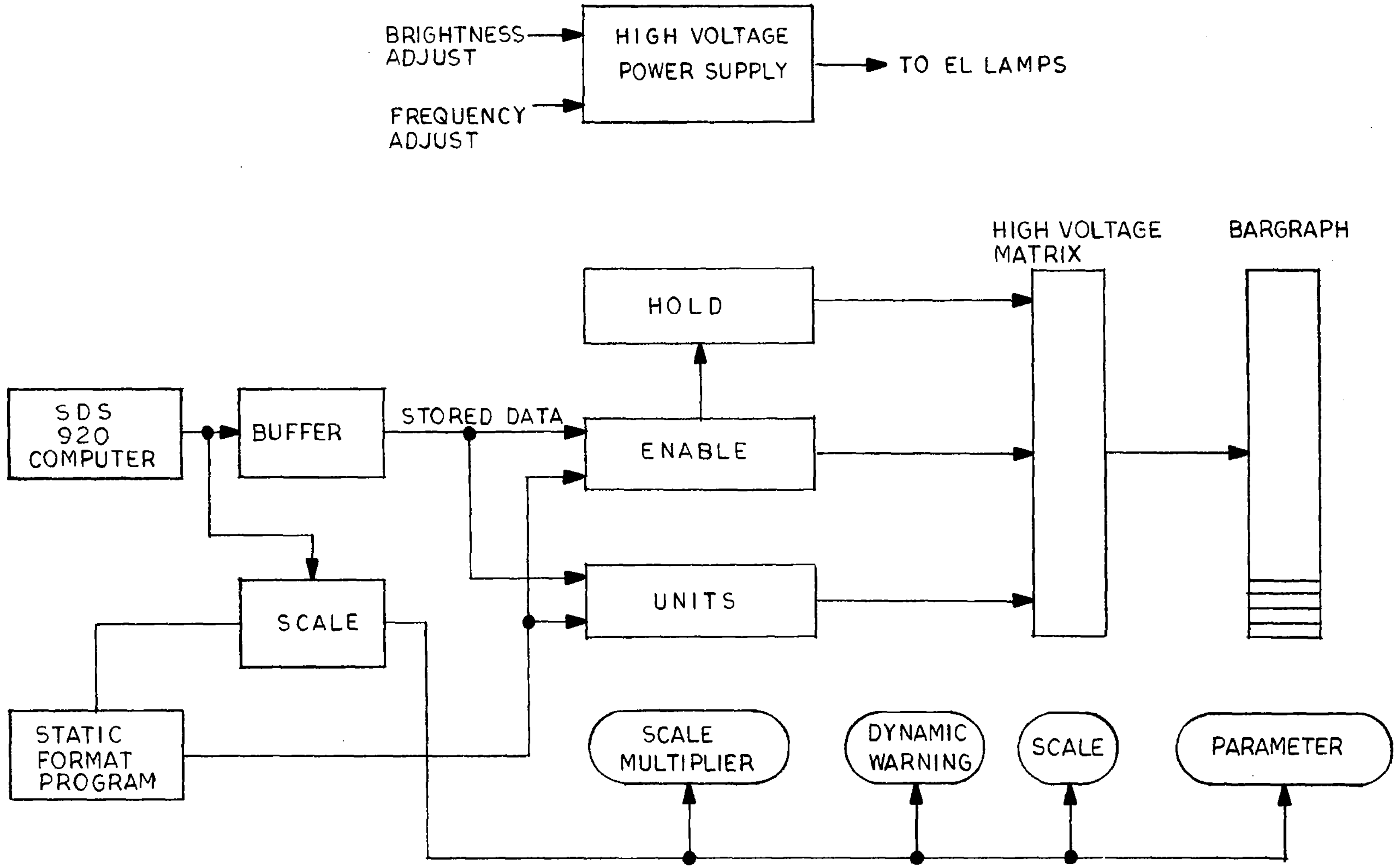
The stored data in the scale module directly drive the scale multiplier, the dynamic warning scale, and the parameter indicators. The Static Format program sets the desired scaling and also the desired Display Format such as pointer or bargraph mode. This programming can be provided by the SDS computer if desired.

The high voltage AC required to excite the EL lamps is generated internally by a DC to AC converter. This converter provides automatic brightness regulation for the EL lamps and also provides a brightness level adjustment.

The theory of operation of the indicator from a functional standpoint is shown in Figure 2.

Logic and Electronic Developments

Bargraph. - In order to meet the design requirements it was found necessary to employ an electronic design technique utilizing high voltage logic and low voltage logic. If low voltage logic were employed to decode 128 outputs from the input data, a minimum of 128 "and" gates would theoretically be required. Practical design restrictions would require more than 128 gates.



FUNCTIONAL OPERATION

FIG.2

The design technique used required only 24 comparable low voltage "and" gates resulting in a power savings of more than 5:1.

The high voltage logic used does not add additional power and therefore a power savings of more than 5:1 is realized. The significance of this design technique must be emphasized since the low voltage logic used consumes only 500 milliwatts and the conventional use of the logic alone would exceed the indicator power requirements.

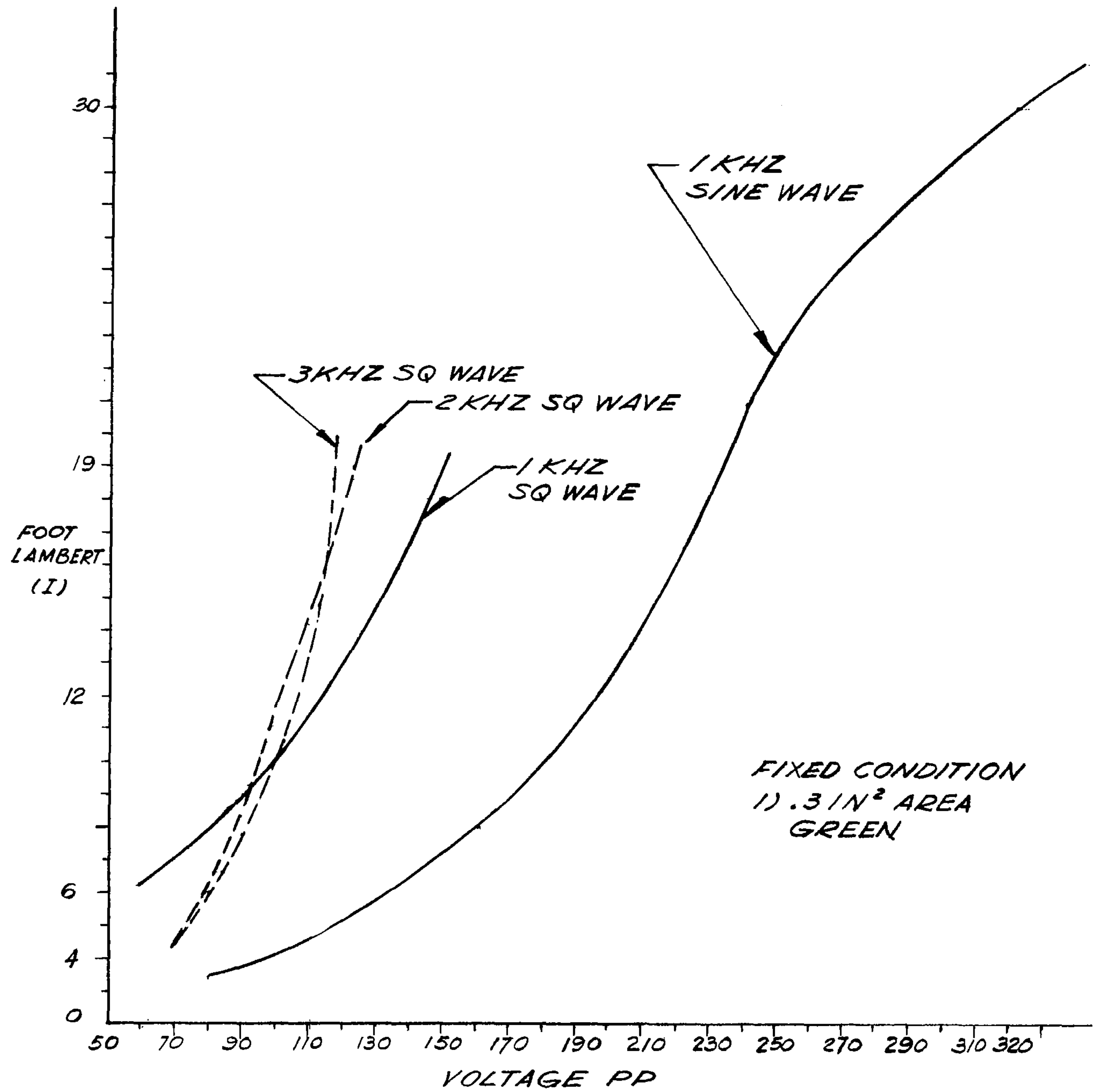
<u>EL Switching Control</u>. - Out of the many possible circuit elements available for electroluminescent lamp AC voltage switching such as photoconductors, transistors, transformers, relays, ferroelectrics, SCR, silicon controlled switches and others, the high voltage transistor and silicon controlled switches were chosen due to their compatibility with the high dynamic response, low power, and purity of display requirements.

<u>Brightness Regulator</u>. - The design technique employed for the brightness regulation uses a feedback system with an external sensor matched to the viewed EL lamp. Attempts to monitor the actual viewed lamp were adversely influenced by ambient light which the self contained sensor unit eliminates. The technique utilized controls the amplitude and wave shape of the EL excitation voltage. During the breadboard phase frequency control was attempted but caused unwanted color shifts in the EL lamps.

Probably the most outstanding difficulty involved with brightness regulation was the selection of a brightness sensing device. Although the brightness regulator was designed for long time aging effects a sensor which is fast enough to follow the EL brightness pulses can cause unwanted problems. Along with the sensor response time the frequency of the EL excitation voltages and the sensing light level must also be considered. The photoconductor used was a cadmium sulfide type which has good spectral and level match characteristics and begins to average individual light pulses at approximately 600 Hz. At a frequency of 2K Hz the photoconductor presents an average light level to the regulator.

A very important requirement on the regulator design was the voltage swing required to provide regulations of a light level throughout the EL lamp lifetime.

As excitation frequency is increased the voltage amplitude required decreases significantly from 400 Hz to approximately 2K Hz and further frequency increases did not appreciably decrease the voltage swing requirement. Figure 3 illustrates this phenomena.



VOLTAGE REQUIRED FOR CONSTANT BRIGHTNESS

FIG 3.

With 250V RMS breakdown rating a peak to peak of 700V is the maximum allowable. To hold 15 foot-lamberts assuming a 2:1 brightness drop at end of life for green phosphors:

With an excitation of 400 Hz, 200 V pp change is required initially and 700V pp breakdown voltage is required at end of life.

With an excitation of 1KHz, 100 V pp change is required initially and 325 V pp is required at end of life.

With an excitation of 2KHz, 20 V pp change is required initially and 150 V pp is required at end of life.

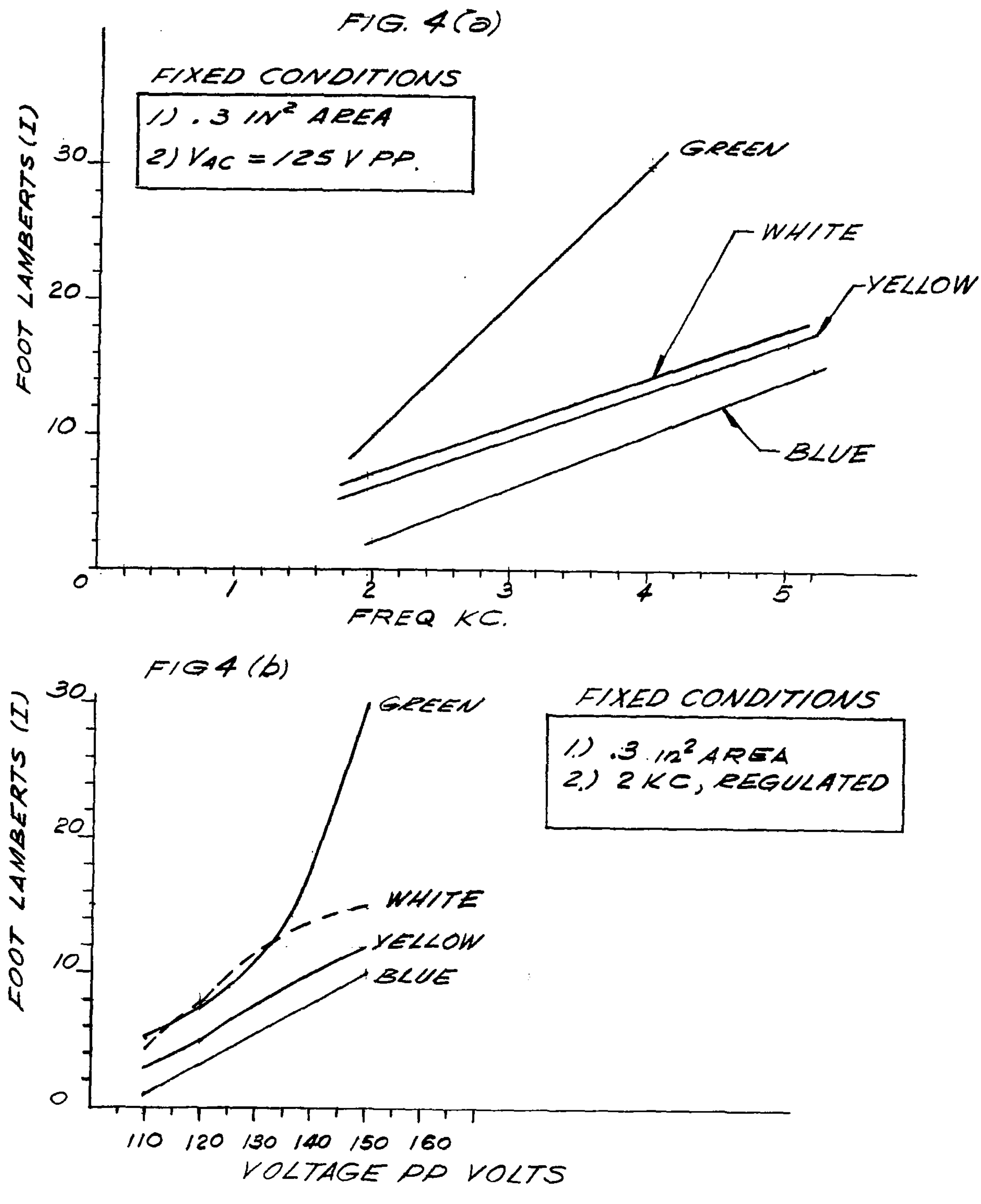
Since white, yellow, and blue phosphors are less than one-half as efficient as green phosphors, they could not possibly be regulated at 400 Hz. 1KHz operation would be borderline and 2KHz would be a practical excitation.

Additional brightness adjustments were found necessary to compensate for multicolor configurations. The four different color phosphors were found to have different excitation characteristics, as shown in Figure 4, which are compensated for by series resistances to match initial brightnesses of the lamps. These adjustments are numbered and located on the rear of the EL lamp connector panel. Table I gives the adjustment number and lamp correlation.

Figure 4a illustrates that the light intensity versus frequency slope is similar for the white, yellow, and blue colors. Green has an apparent slope increase of about 3:1 over the other colors indicating its uniqueness.

Figure 4b illustrates that the white, yellow, and blue colors are similar in their response to voltage excitations. The white, yellow, and blue show linear response while the green shows a non-linear response. The changing slope shows the efficiency of the green color in that at low brightness levels it is similar to the other colors, but at higher brightness levels the slope increases by a factor of 2:1 over the other colors.

The results show that a trade-off exists between voltage drive range, brightness, and efficiency. Without brightness regulation a low frequency excitation appears most efficient. Low frequency excitation is possible as long as the brightness required at end of life can be obtained with an excitation voltage less than the voltage breakdown potential. Using brightness regulation by voltage control the low frequency mode requires very large voltage swing capability. Large voltage swings cause regulator inefficiencies, or voltage step up ratios, that impose serious design restrictions on the regulator accuracy.



MULTICOLOR EXCITATION COMPATIBILITY

FIG. 4

Four hundred hertz operation would not be practical under any circumstances. One thousand hertz operation would be borderline for all colors but practical for green. Two thousand hertz operation allows sufficient design tolerance and was chosen for the instrument design.

Low frequency-high voltage EL lamp excitation presents problems due to high currents at turn on and turn off, since a fixed size EL is a relatively constant capacitance and Q=CV. As the voltage increases a larger Q must be transported. $\frac{dQ}{dt}$ is current and must then be controlled by $\frac{dV}{dt}$ or damage to the EL lamp will result. At 400 Hz a voltage of more than 7 times that of 2K Hz is necessary to achieve brightness levels of 15 foot-lamberts.

Logic and Electronic Design

Two configurations of the vertical scale indicator were designed. These are the single parameter indicator employing a single bargraph with scale and parameter indication, and the flight director indicator employing two adjacent bargraphs with scale and parameter indication.

The vertical scale indicator receives signal inputs from a Scientific Data Systems Model 920 digital computer. These signals consist of:

1) A seven-bit binary number which represents the value of the variable used for the bargraph function.
2) A two-bit scale indication.
3) A four-bit parameter indication.
4) A 4.6 microsecond data strobe.

Signal inputs supply only true signals, no complements are available.

Input signals are conditioned by line receiver circuits and are stored in buffer memory circuits. The line receivers will withstand input signal overloads of positive and negative 30 volts without damage so that correct operation is obtained even at these signal levels. The input signals are gated by the 4.6 microsecond wide strobe signal into the buffer memory. The memory retains this data until the next updating strobe signal is received. Updating can be accomplished at rates from zero to over 1000 times a second.

The electronic logic design of the basic instrument has been separated into three functions:

1) The bargraph function.
2) The scale function.
3) The parameter function.

The basic building blocks are logic sticks with suitable combinations of electronic elements such as gates, switches, and drivers in microcircuit form.

Bargraph Function. - The logical design of the bargraph function is shown in Figure 5. The bargraph is generated from the seven-bit binary signal by decoding the binary data into a signal which activates the segmented electroluminescent (EL) lamp. The height of the lighted segments (top segment and all below it) is proportional to the value of the variable indicated by the seven-bit code in the bargraph mode. The pointer mode allows an indication using only the lighted top segment.

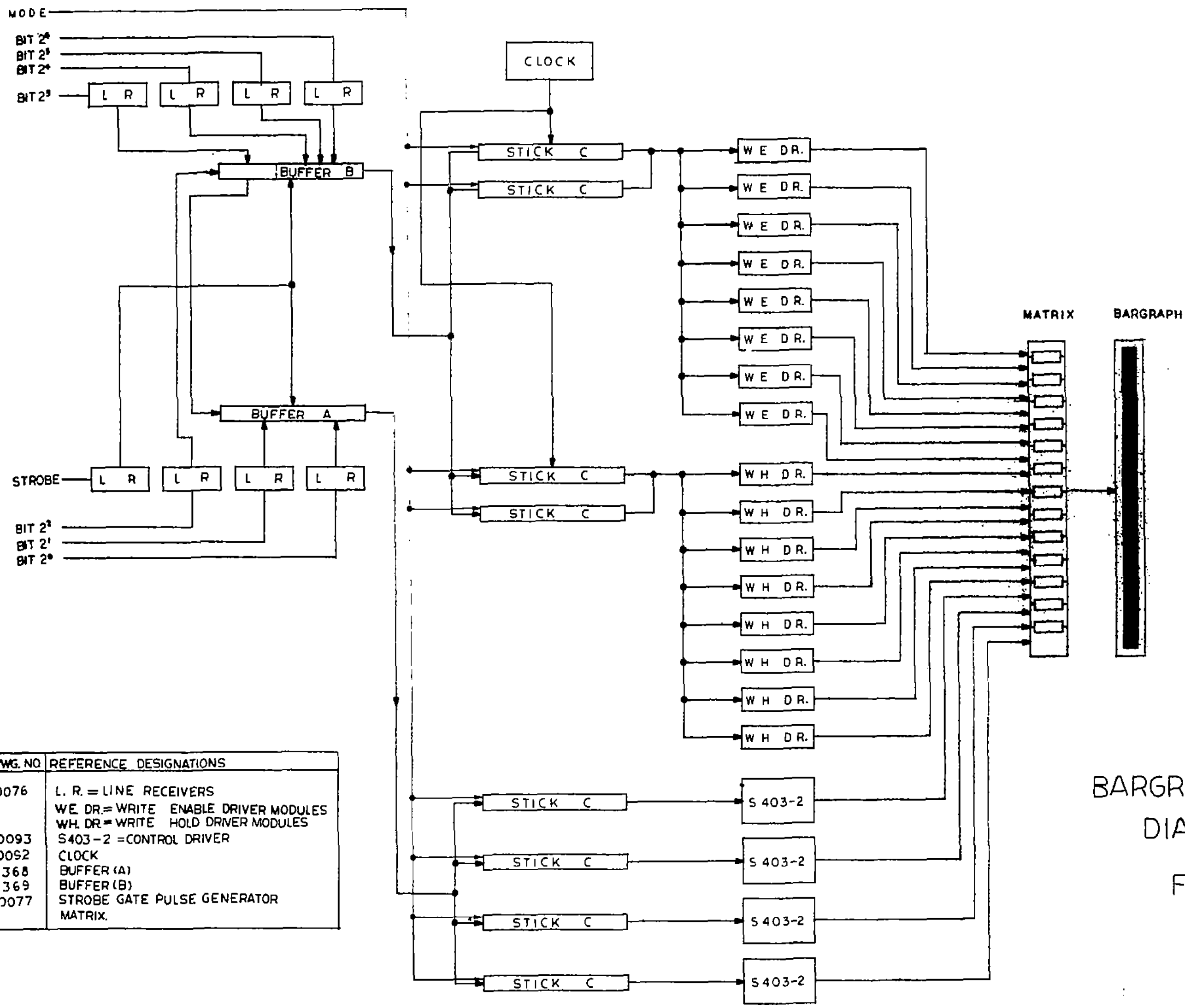
Signals from the buffer memory logic sticks are channeled through the bargraph decoding sticks to the writers which energize the EL lamp segments through the matrix.

As compared with the initial design, the development effort has reduced the amount of electronic logic necessary to provide the bargraph display. The items required to provide the bargraph function are:

1) Buffer module
2) Units logic/writer module
3) Hexadecade write-enable module
4) Hexadecade write-held module
5) Display matrix
6) Segmented EL lamp

Buffer Module. - The buffer module contains eight line receivers to provide the interface signal input to seven strobe-gated DTL flip-flop microcircuits contained on two microcircuit logic sticks. The buffer module also contains a clock generator which provides gating for the hexadecade logic drivers.

Units Logic/Writer Module. - The units logic/writer module contains four microcircuit logic sticks, which in turn contain six microcircuit DTL flat packs each, to provide the decoding for sixteen writer drivers. The module also contains sixteen APRC Type S403-2 writers which provide an output to the EL matrix. A carry-down function is contained in the logic stick so that all unit drivers below that being decoded are also activated to generate a bargraph. This carry-down is disabled to provide the pointer mode.



MODE LOGIC

MODE · LINE	MODE
0 V	POINTER
+5 V	BARGRAPH.

DRWG. NO	REFERENCE DESIGNATIONS
50076	L. R. = LINE RECEIVERS
	WE. DR. = WRITE ENABLE DRIVER MODULES
	WH. DR. = WRITE HOLD DRIVER MODULES
50093	S403-2 = CONTROL DRIVER
50092	CLOCK
11368	BUFFER (A)
11369	BUFFER (B)
50077	STROBE GATE PULSE GENERATOR
	MATRIX.

BARGRAPH FUNCTION DIAGRAM

FIG. 5

Hexadecade Write-Enable Module. - The hexadecade write-enable module contains two DTL microcircuit logic sticks which decode the eight groups of sixteen units that comprise the 128 bit bargraph decoding. The decoding sticks drive eight APRC Type S101 write-enable drivers, providing hexadecade control to the EL matrix. A carry-down function is contained in the logic stick so that all hexadecade drivers below that being decoded are activated to generate a bargraph.

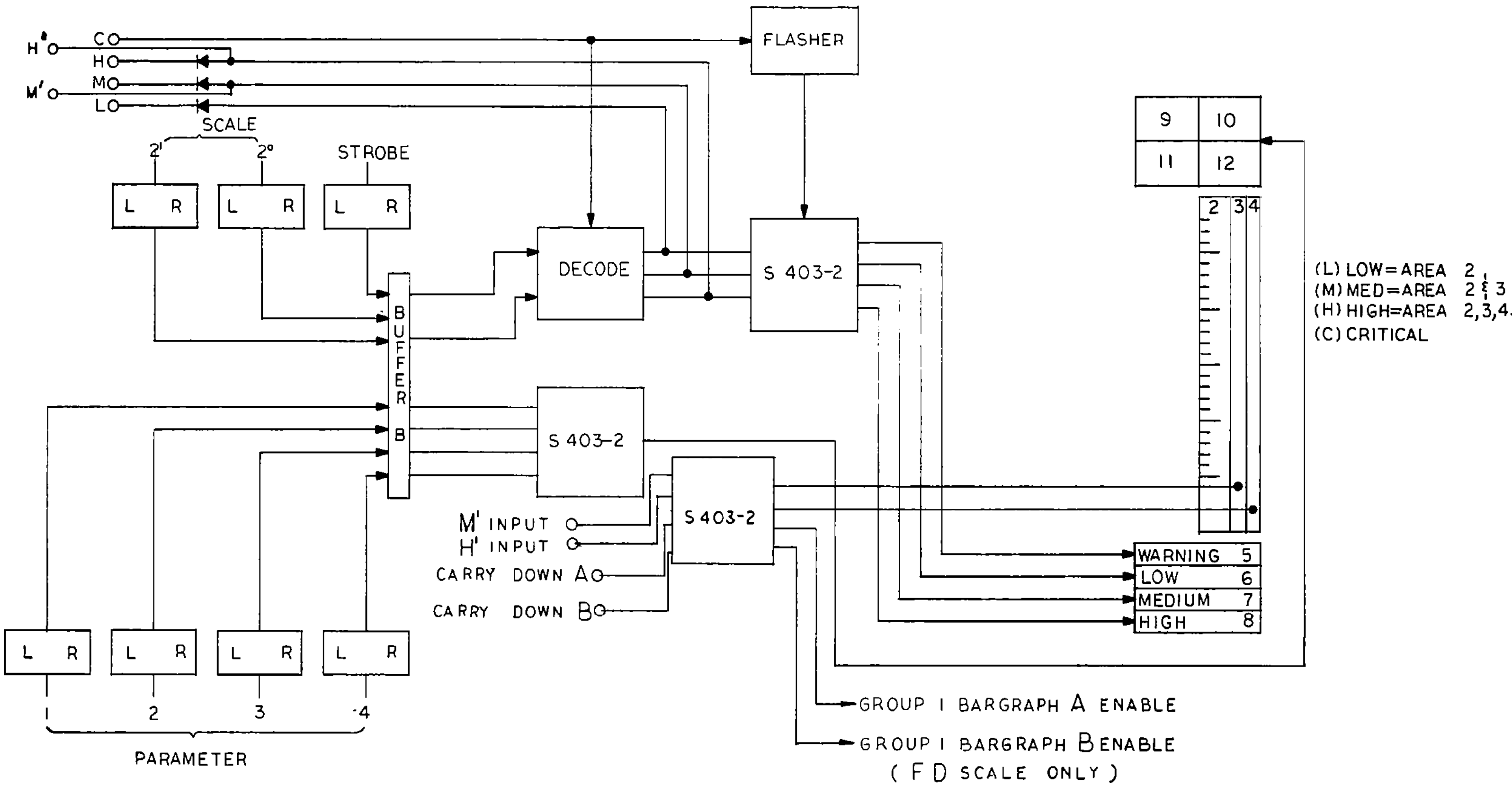
Hexadecade Write-Hold Module. - The hexadecade write-hold module contains two DTL microcircuit logic sticks which decode the eight groups of sixteen units that comprise the 128 bit bargraph decoding. The decoding sticks drive seven APRC Type S102 drivers, providing hexadecade control to the EL matrix. A carry-down function is contained in the logic stick so that all hexadecade drivers below that being decoded are activated to generate a bargraph.

Display Matrix. - The display matrix is comprised of 384 (3 x 128) high-voltage microdiodes mounted on a welded assembly which contains the EL lamp mating connector. The display matrix provides isolation control for the hexadecade writer functions.

Segmented Bargraph EL Lamps. - The bargraph lamps contain 128 individually lightable segments which are driven by the display matrix to display the information presented by the display matrix.

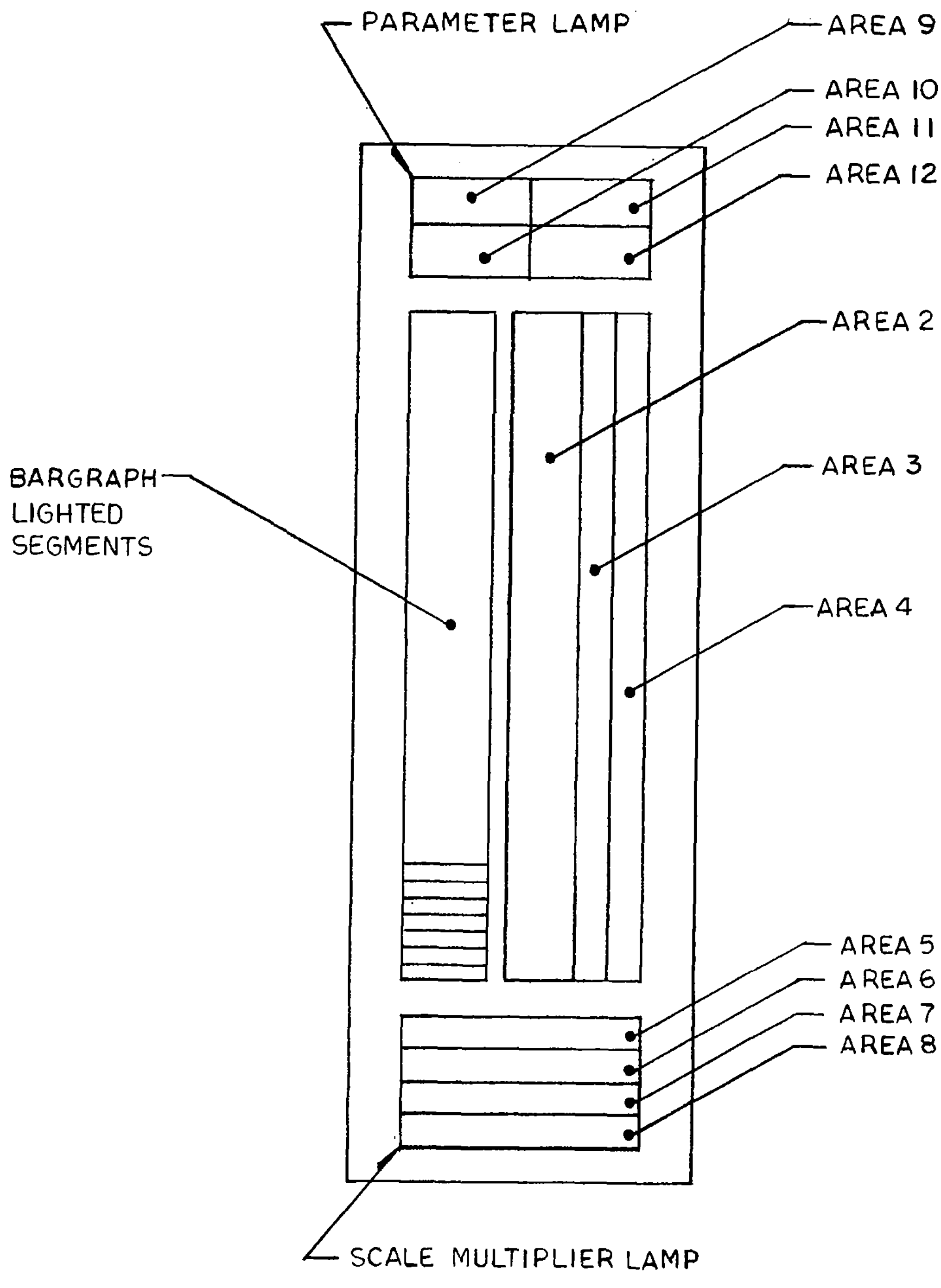
Scale Function. - The logical design of the scale function is shown in Figure 6. For indications of scaling, various EL lamp areas are illuminated, depending on the coding of the two-bit input signal and external jumpers at the indicator input connector. Table II and Figure 7 indicate the coding and jumper logic. Area 5 is excited as a warning signal. If the scale coding is such as to activate this area, the flasher function is energized and gates the EL lamp area 5 writer at a rate variable from one to ten Hz. The flasher frequency is adjustable by a screwdriver-type adjustment.

The scale function is contained in a portion of the scale-parameter module. The scale portion contains two line receivers to provide the interface function for the signal input to two strobe-gated DTL flip-flop microcircuits contained on a portion of a microcircuit logic stick. The stored scale coding data drives a DTL microcircuit decoder whose output drive four APRC type S403-2 writers for EL lamp areas 6, 7, and 8. The external jumper logic is performed by gating the writer inputs. Area 2 is always energized and the combination of energized areas 6 and 2 indicates low scale. Area 3 is energized from the area 7 writer drive, and the combination of energized areas 7, 2, and 3 indicates medium scale. Areas 4 and 3 are



DRWG NO.	REF. DESIGNATION
50076	L.R.=LINE RECEIVER
11369	BUFFER(B)
50093	S 403-2 CONTROL DRIVER MODULES
50094	FLASHER

FUNCTIONAL DIAGRAM
SCALE, PARAMETER
FIG. 6



LIGHTED AREA IDENTIFICATION

FIG. 7

energized by the area 8 writer drive and high scale is indicated when areas 8, 2, and 3 and 4 are energized. In addition, scale areas 3 and 4 can be separately energized by external jumper logic.

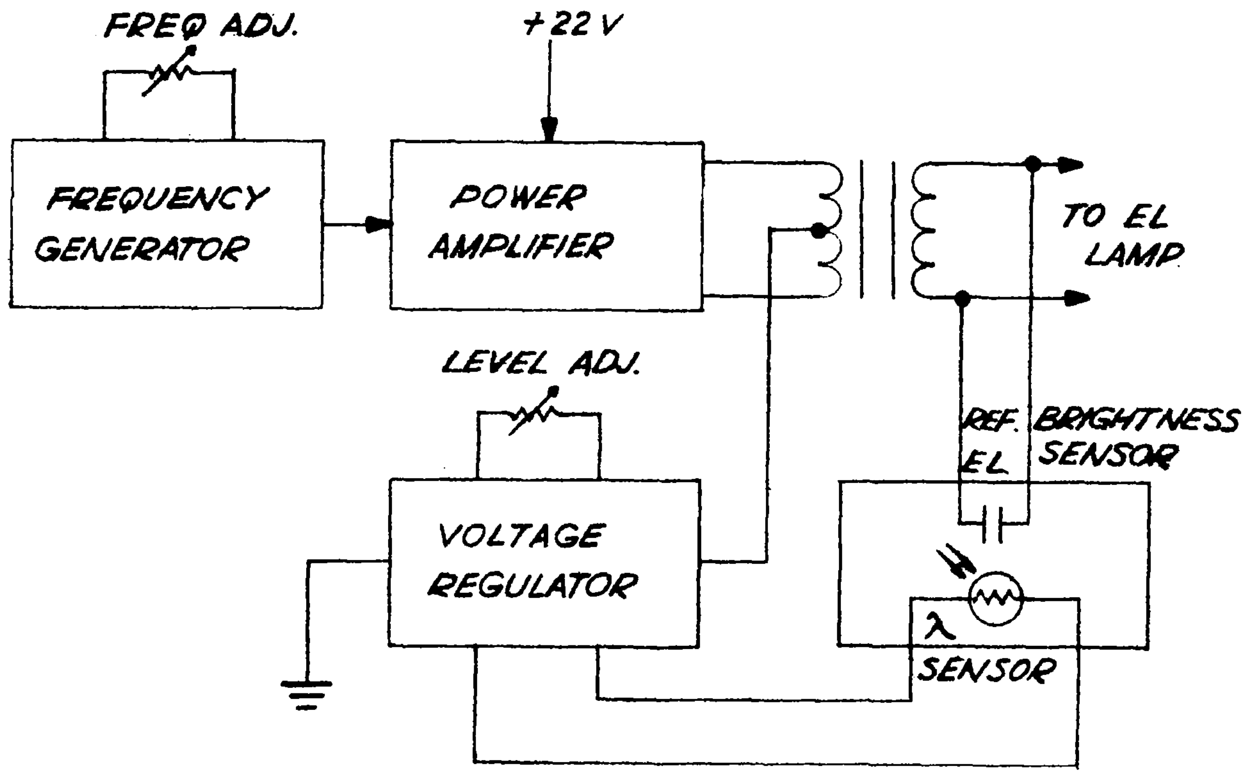
Connections used for the scaling function jumper logic, using Table II, depend upon desired scales. For the back lighted side scale zero to ten will be lighted at all times. The lighting of zero to one hundred or zero to one thousand can be accomplished in two ways. If the M' input signal is returned to signal ground the zero to one hundred will be lighted at all times. If the H' input signal is returned to signal ground the zero to one thousand will be lighted at all times. Leaving the M' input and H' input signal lines open will provide a zero to ten scale. Connecting the M' input and H' input signals will provide automatic side scale programming with the scale multiplier program. The warning function is programmed by connecting either the L, M, or H signal to the C signal. This allows the warning indication to coordinate with the scales. If it is desired to have the warning light energized at 50% of the low scale to denote some desired low altitude the L and C would be connected. The warning would be energized by the computer changing the scale binary code from 01 to 00 at the 50% point by the computer program. The flexibility of scaling available is limited only by the ingenuity of the computer programmer.

Parameter Function. - The logical design of the parameter function is shown in Figure 6. The name of the parameter being displayed is indicated by energizing one or more of the parameter EL lamp areas 9, 10, 11, 12. The parameter function is contained in a portion of the scale parameter module.

The four bit parameter indication signal is received by four line receivers which provide the interface signal input to four strobe-gated DTL flip-flop microcircuits contained in a portion of the microcircuit logic stick. The stored parameter bits drive four APRC Type S403-2 writers for areas 9, 10, 11, and 12.

Constant Brightness Regulation Function. - The design of the constant brightness regulator is shown in Figure 8. The constant brightness regulation is contained in the rear interconnect assembly and provides a variable-frequency, controlled-amplitude power source for the EL lamps. A sensor monitors the lamp brightness to provide feedback into the control system. The controlled EL lamp and sensor are matched to introduce the proper error factor into the feedback system.

The regulator utilizes a unijunction frequency generator which drives a multivibrator for duty factor correction. The multivibrator drives an



BRIGHTNESS REGULATOR FUNCTIONAL

FIG 8

output isolation stage which drives a step-up transformer. The regulation is provided by controlling the primary amplitude with the feedback system. If the EL lamp output tends to decrease, a photoconductor senses the change and drives an amplifier to provide negative feedback, thereby increasing the primary driving amplitude and causing the EL lamp brightness to remain within ±10 per cent of the set level of brightness.

EL lamp brightness is also manually adjustable to any desired brightness within the characteristic range. The brightness so adjusted will automatically remain controlled at that level although the regulation accuracy may be somewhat degraded.

The brightness regulator will control the EL lamp outputs within ±20 per cent of nominal brightness for the 1000-hour nominal lifetime.

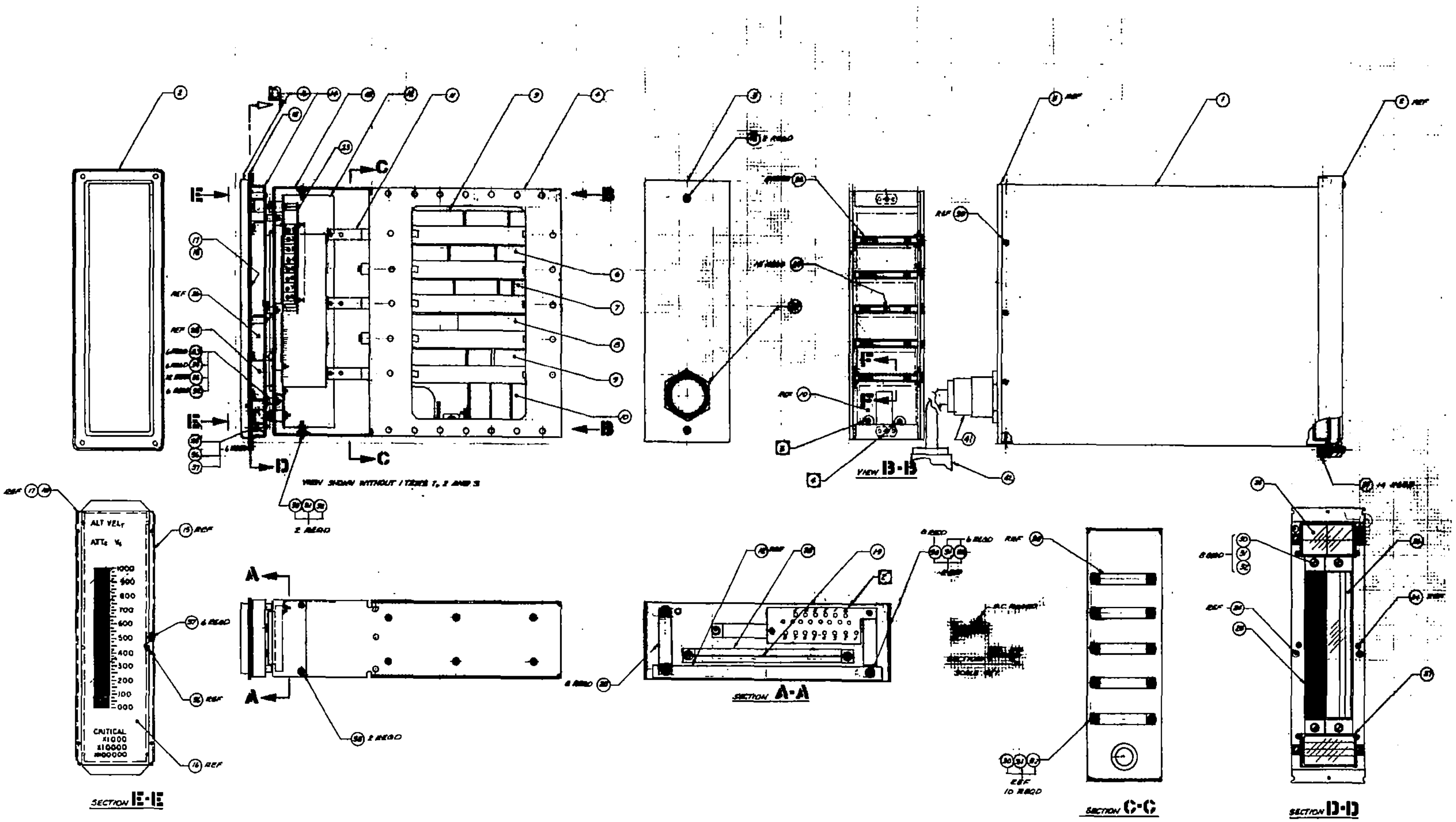
Mechanical Design

The electroluminescent vertical scale indicator has been mechanically designed for an efficient configuration with respect to size and weight consistent with producing a high quality instrument for simulator use. The packaging design considerations included those particular conditions imposed on spacecraft instruments. Ease of maintainability, adjustment, and manufacture were also important factors in determining the design.

The delivered indicators were two single parameter and one flight director unit. The physical configuration of the single parameter unit is as follows: weight:- approximately five pounds; and overall case dimensions:- approximately 7-1/2" high, 9-3/4" length, and 2-1/2" wide. The single parameter indicator is shown in the photographs on pages 32 and 33 in the final configuration. The flight director unit shown on page 34 weighs approximately eight pounds with overall case dimensions of approximately 8-1/2" high, 9-3/4" length, and 3-3/4" width. Significant size and weight reduction is possible for flight versions of these simulator units.

Single Parameter Indicator. - The mechanical design of the single parameter indicator is illustrated in Figure 9. The basic assemblies which comprise the single parameter indicator are:

1) Case and bezel
2) Cover glass
3) Scale mask
4) EL lamp mounting panel
5) EL lamp connector
6) Module connector panel
7) Module card cage



SINGLE PARAMETER ASSY
FIG 9

4 FREQUENCY ADJUST
5 BRIGHTNESS CONTROL

Case and Bezel. - The case and bezel are flat black in color, and constructed of aluminum to reduce weight. The back of the case is removable for access to electrical adjustments.

Cover Glass. - The cover glass is surface treated with High Efficiency Anti-Reflection coating to reduce reflections. The cover glass is a double glass laminated circular polarized filter. The HNCP37 polarized neutral density filter allows 40% transmission from the EL display.

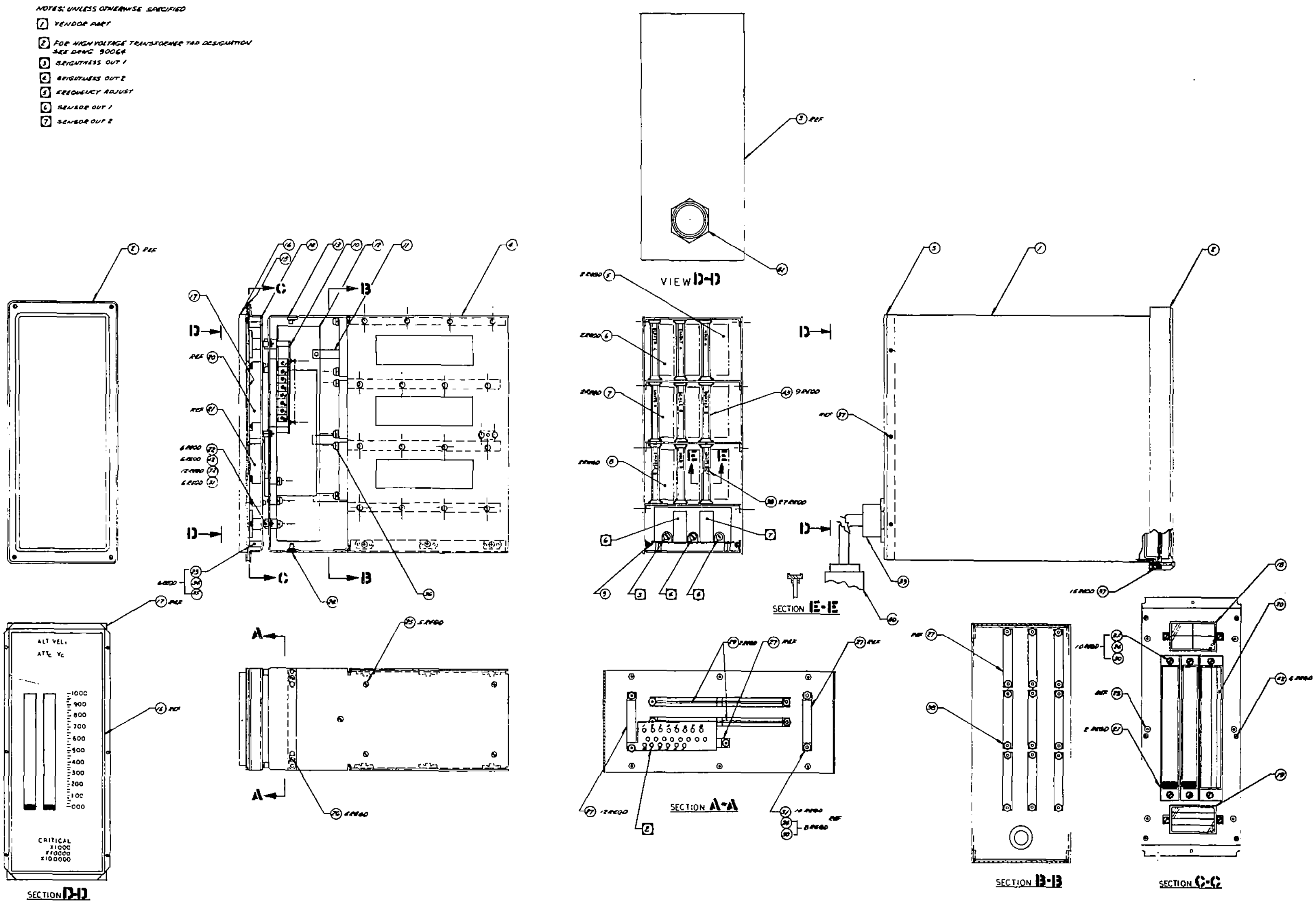
Scale Mask. - The scale mask provides transparent scale markings and is located to the EL lamp mounting plate by four positioning pins through holes in the mask. Fine adjustment of the mask positioning is available so that the mask scale markings can be located within 0.01 inch as to the segmented EL lamp value indications. The mask can be easily removed by lifting it from the locating pins.

EL Lamp Mounting Panel. - The EL lamp mounting panel provides the location accuracy base for the EL lamp and the scale mask. The EL lamps are also secured to this panel with screws for mechanical stability. Fine adjustment is provided for the individual EL lamp location to meet the registration accuracy specification. The EL lamp mounting panel secures to the EL lamp connector panel.

EL Lamp Connector Panel. - The EL lamp connector panel provides the mating connector for the EL lamps. The panel connectors are mechanically floating since the lamps are located to the EL lamp mounting panel and not the mating connectors. A space exists between the EL lamp connector panel and the EL lamp mounting panel to allow the alignment screws to engage before the EL lamp and mating connectors engage when attaching and connecting the plug-in EL lamps.

Module Card Cage. - The module card cage provides for the securing of the module cards. The cage is constructed from formed aluminum stock for low weight and mechanical stability. Card guides are provided that conserve instrument width. It also provides mounting structure for the module connectors and a hinge arrangement for ease of accessability to the wiring and harnessing which electrically connects the modules to the EL lamps.

Flight Director Indicator. - The mechanical design of the flight director indicator is illustrated in Figure 10. The instrument design is similar to that of the single parameter indicator except for the inclusion of an additional segmented EL lamp and its associated modules. These additions cause an increase in mechanical size over that of the single parameter instrument. Module cards and EL lamps are interchangeable between the flight director indicator and the single parameter indicator with the exception of the scale module.



FLIGHT DIRECTOR ASSY
FIG 10

Circuit Packaging. - Module packaging is illustrated on page 33, and drawings of the basic instrument construction techniques are shown in Appendix " E ". The logic integrated circuit flat packs are packaged in micro-circuit logic sticks. The flat packs are welded to comb subassemblies which provide for the flat pack interconnection. This form of microcircuit packaging provides the highest density packaging presently available for flat packs. The logic sticks also eliminate the need for multilayer circuit boards. All other associated circuitry is encapsulated in replaceable cases which are soldered to the circuit board modules. All electronic components are hermetically sealed.

Auxiliary Equipment

The auxiliary equipment supplied with the indicators consists of a computer signal simulator and component spares.

Computer Signal Simulator. - The computer signal simulator unit houses the external power supplies adequate for simultaneous operation of four single parameter indicators. The power supplies consist of two isolated and regulated d.c. outputs of nominal 4.5 volts and 22 volts. Both outputs are adjustable ±10 per cent of nominal. The 4.5 volt supplies the logic circuit power and the 22 volt output supplies the EL lamp power.

The computer signal simulator will enable either a single parameter or a flight director to be exercised statically in all modes with all possible combinations of input signals.

This is accomplished by toggle switches for selection of bargraph, mode, scale, and parameter input data. A one-shot multivibrator supplies the data strobe when activated by a push button switch. A jumper test point arrangement is provided for the scale warning signal simulation. The externally housed computer simulator unit is connected to an indicator by a cable assembly with quick disconnect Bendix type connectors. This unit also containing running time meter to enable an accumulation of indicator energized time if desired.

Equipment and Spares Delivered. - The hardware provided for this program consisted of lamps, modules, cables, and chassis. The items delivered are listed in Table III, included at the end of this report as Appendix " C". The delivered equipment provides the capability of operating four single parameters or two flight director indicators if desired.

EL Development

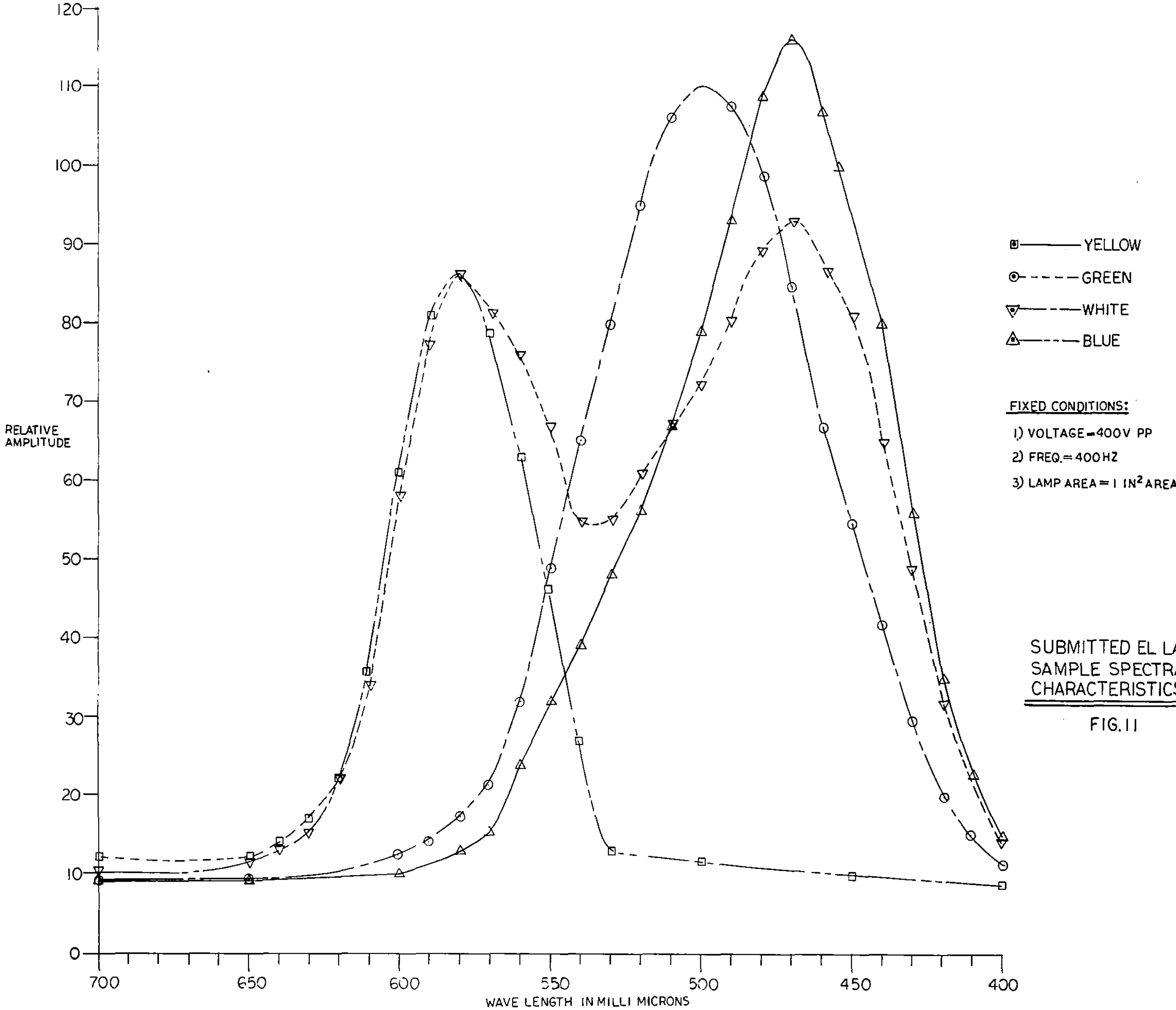
Introduction. - In order to provide the high contrast, high resolution, multicolor lamps required for this program a development program was undertaken. The purpose of this program was to further improve available EL materials and techniques necessary to support EL lamp fabrication. The major investigation areas were contrast enhancement techniques, high resolution fabrication techniques, and excitation characteristics.

Survey. - The development program was begun by a survey of previously developed APRC EL fabrication techniques and the existing state-of-the-art techniques. This study indicated that the required lamps were not available as off-the-shelf items within the overall program schedule and budget commitments.

Although APRC has the capability of complete lamp fabrication, the approach taken involved the use of previously developed APRC manufacturing techniques to assist lamp manufacturers in the production of the required EL lamps. An Electroluminescent Indicator Lamp procurement specification was prepared and submitted to five major EL lamp manufacturers and subsequent negotiations defined the lamp fabrication approach. The basic construction technique selected was an organic phosphor binder using a glass substrate. The significance of the basic construction technique is that it greatly affects the electro-optical and environmental performance.

The program requirement of 15 foot-lambert brightness capability, after one thousand hours operation and low power operation, more or less determined the basic lamp construction technique. While the metal back ceramic phosphor-binder technique provides excellent environmental qualities, the phosphor efficiency is degraded by the process. Plastic substrate lamps are not recommended for space applications, because of space environmental conditions. Phosphors are adversely affected by moisture and a true hermetic seal technique has not been developed. Thin-film lamps appear less efficient than the bulk construction with normally shorter usable lifetime.

Electroluminescent Lamp Development. - The electroluminescent lamps were fabricated at Aerospace Products Research Corporation from substrate panels supplied by Sylvania Electric, Emporium, Pa. Color sample panels of 400 Hz, 115V rms, green, blue, white and yellow were initially provided and through mutual efforts of phosphor mixture, contrast, and conductive film changes a final form was selected. The spectral characteristics of these colors are shown in Figure 11. Dyes alone applied to the phosphor binder for contrast enhancement resulted in excessive loss of brightness and so a combination of binder darkening and substrate glass filtering was utilized.



SUBMITTED EL LAMPS
SAMPLE SPECTRAL
CHARACTERISTICS

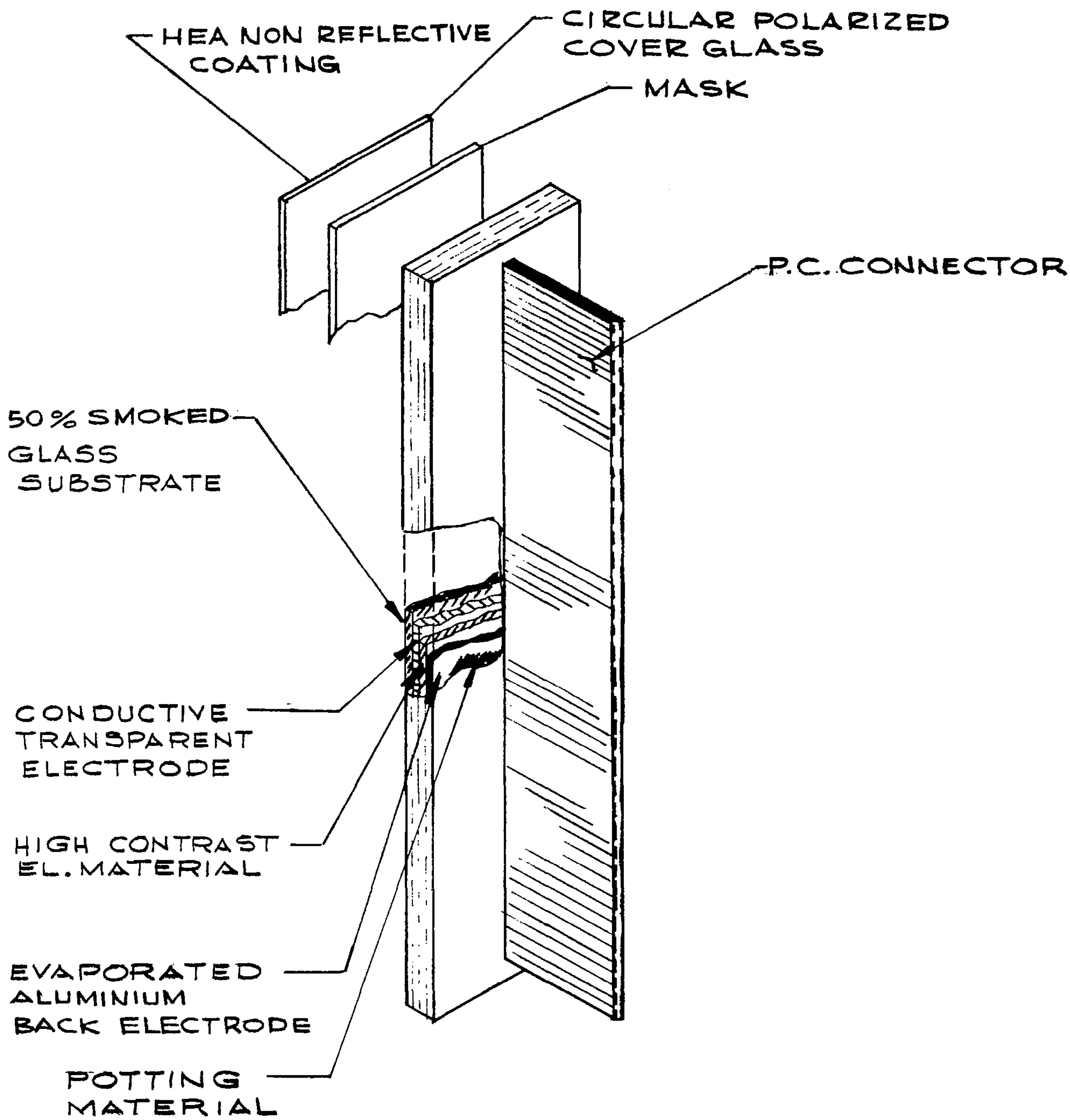
FIG. 11

The high contrast technique utilized was used for efficiency and versatility. Total contrasting was not placed internal to the EL lamp since a plastic mask and instrument cover glass must also be considered. The contrast enhancement was accomplished external to the lamp by a circularly polarized HNCP37 neutral density 40% transmission indicator cover glass and internal enhancement which allows approximately 70% transmission. An HEA coating was used at the viewer interface to minimize reflections. A two stage contrast enhancement technique was used for efficiency and versatility. Some contrasting internal to the lamp is necessary to suppress unwanted lighting of adjacent de-energized segments from reflected light.

EL Lamp Design. - The EL lamps utilized for the bargraph, background scale, scale multiplier, and parameter indications were fabricated in the four colors, green, blue, white and yellow as shown in Figure 12. Each lamp was built on a glass substrate of .120 inch thickness. A scribing technique was utilized such that the phosphor dielectric of each lighted area is separated. This technique provides significant segment to segment cross talk reduction since there is no common dielectric. Segmented displays with resolution up to thirty-two lines per inch were successfully fabricated. From a fabrication standpoint, the scribing technique does not limit finer resolution. Unlighted scribe line widths of .001 to .005 inch were obtained such that 80 to 90% of the segmented area can be lighted.

The fabrication item limiting finer resolution is the electrical connections which are required for each segmented area. It is not the magnitude of connections rather the density which affects both cost, reliability and fabrication feasibility. A printed circuit board plug-in interface was chosen for lamp interchangeability. Wired connections were then made from each segment to the printed circuit board. This technique is amenable to low cost fabrication by providing deposited type connections between the lamp rear electrode and the printed circuit boards.

The entire lamp assembly is sealed in epoxy and housed in an aluminum boat structure. The metal housing provides mechanical stability and rigidity for the EL lamp. Lamps fabricated by this technique have been operated from 0° to $140^{\circ}F$ without appreciable degradation.



HIGH CONTRAST EL LAMP CONSTRUCTION

FIG. 12

CONCLUSION

The delivery and subsequent acceptance of two single parameter and one flight director solid state indicators capable of operating at computer speeds represents a significant advancement in the state-of-the-art. It was felt that the program objectives were exceeded in many areas.

Further development in the areas of space quality EL lamps, human factors evaluation, and flight packaging are necessary before these simulator prototypes can be utilized in the cockpit. An excitation of 2K Hz was found to be compatible with brightness regulation.

It was found that the capability of providing 15 foot-lamberts for 1000 hours was marginal for green EL lamps and not possible for yellow, white, and blue ones at 400 Hz excitation, due to a voltage requirement that is greater than breakdown.

Substantial reductions of weight and size are possible and can be easily accomplished at the cost of mechanical flexibility (since connectors occupy approximately 30% of the indicator volume); however, weight and size were sacrificed in order to optimize the prime objectives.

The performance objective of compatibility during computer operation was found to be better than expected. In order to achieve computer compatibility the indicator circuitry mechanization was designed for high speed operation. The use of speed limiting elements such as photoconductors were found unsuitable since they limit updating to hundreds of milliseconds. Computer operation showed an update capability in excess of 1 millisecond which far exceeded the initial objective of 25 milliseconds. The indicator response time exceeds the human eye response time so that the limiting factor for data rates is the person viewing the data.

Initially, it was felt that due to the mechanical tolerances involved there would be a problem of accurate mask alignment to the EL lamps. However, this did not materialize, and the match worked out very nicely.

Multiple indicator operations of two single parameters and one flight director did not indicate any evidence of cross talk between indicators. The single parameter indicator is capable of operating at 2. 5 watts and power consumption is less than four watts at high brightness (15 foot-lamberts) levels.

Appendix A

TABLE I

LAMP AREA - BRIGHTNESS ADJUSTMENT CORRELATION

*POTENTIOMETER ADJUSTMENT #	LAMP AREA
1	9, 10, 11, 12 - Parameter
2	4 - Background, High
3	3 - Background, Medium
4	2 - Background, Low
5	5 - Warning
6	6 - Scale Multiplier, Low
7	7 - Scale Multiplier, Medium
8	8 - Scale Multiplier, High

*See Figures 9 and 10.

Appendix B

TABLE II

SCALE INDICATION LOGIC

Scale Signal Inputs MSB	Scale Signal Inputs LSB	External Jumpers	Lighted Areas	Range
0	0	L to C	2, 5, 6	Low & Warning
0	0	M to C (M^1 to M^1)	2, 3, 5, 7	Medium & Warning
0	0	H to C (H^1 to H^1)	2, 3, 4, 5, 8	High & Warning
0	1	Not Applicable	2, 6	Low
1	0	M^1 to M^1	2, 3, 7	Medium A
1	1	H^1 to H^1	2, 3, 4, 8	High A
X	X	M^1 Input to Grd.	2, 3, at all times	Medium B
X	X	H^1 Input to Grd.	2, 3, 4, at all times	High B

Appendix C

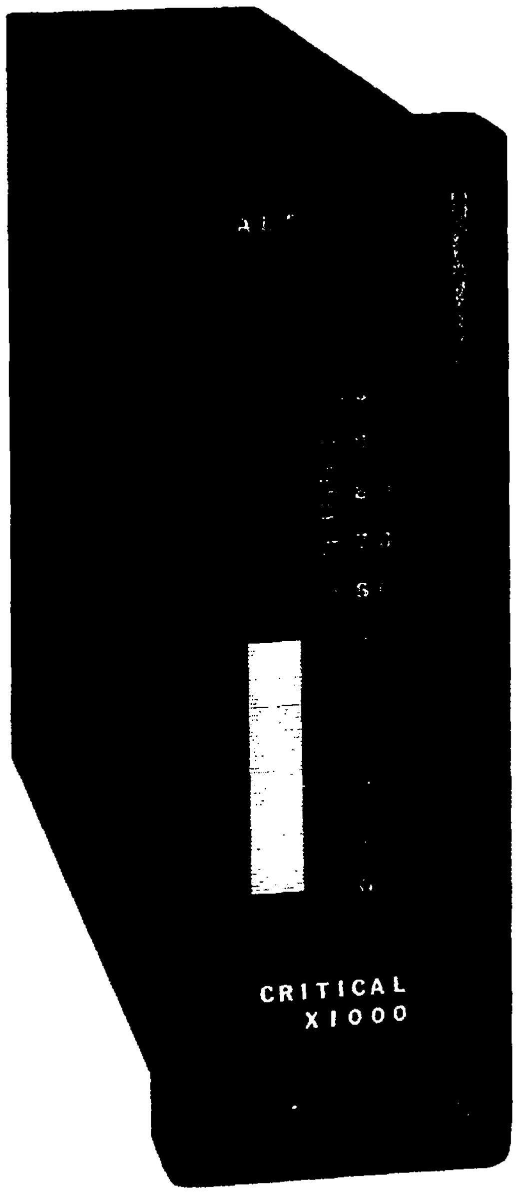
TABLE III

EQUIPMENT AND SPARES DELIVERED

Item	APRC Part No.	Description	Total Qty.
1	90033-1	EL Background Scale Lamp, White	3
2	90033-2	EL Background Scale Lamp, Green	3
3	90033-3	EL Background Scale Lamp, Blue	1
4	90033-4	EL Background Scale Lamp, Yellow	1
5	90035-1	EL Bargraph Lamp, White	2
6	90035-2	EL Bargraph Lamp, Green	6
7	90035-3	EL Bargraph Lamp, Blue	2
8	90035-4	EL Bargraph Lamp, Yellow	2
9	90034-1	EL Scale Lamp, White	3
10	90034-2	EL Scale Lamp, Green	3
11	90034-3	EL Scale Lamp, Blue	1
12	90034-4	EL Scale Lamp, Yellow	1
13	90036-1	EL Parameter Lamp, White	3
14	90036-2	EL Parameter Lamp, Green	3
15	90036-3	EL Parameter Lamp, Blue	1
16	90036-4	EL Parameter Lamp, Yellow	1
17	11385	Brightness Regulator Sensor	8
18	11179	Constant Brightness Regulator	6
19	11333	Display Matrix	8
20	11031	Hexadecade Write-Enable Module	6
21	11067	Hexadecade Write-Hold Module	4
22	11034	Units Write Module	6
23	11336	Bargraph Buffer Module	6
24	11337	Scale/Parameter Module	5
25	11382	Drawer Assembly, Single Parameter	4
26	11386	Drawer Assembly, Flight Director	2
27	11405	Case and Bezel Assy., Single Parameter	4
28	11406	Case and Bezel Assy., Flight Director	2
29	11387	Mask, Flight Director	2
30	11379	Mask, Single Parameter	4
31	11213	Power Supply	1
32	11407	Computer Signal Simulator	1
33	11388	Power/Signal Cable Assembly	6

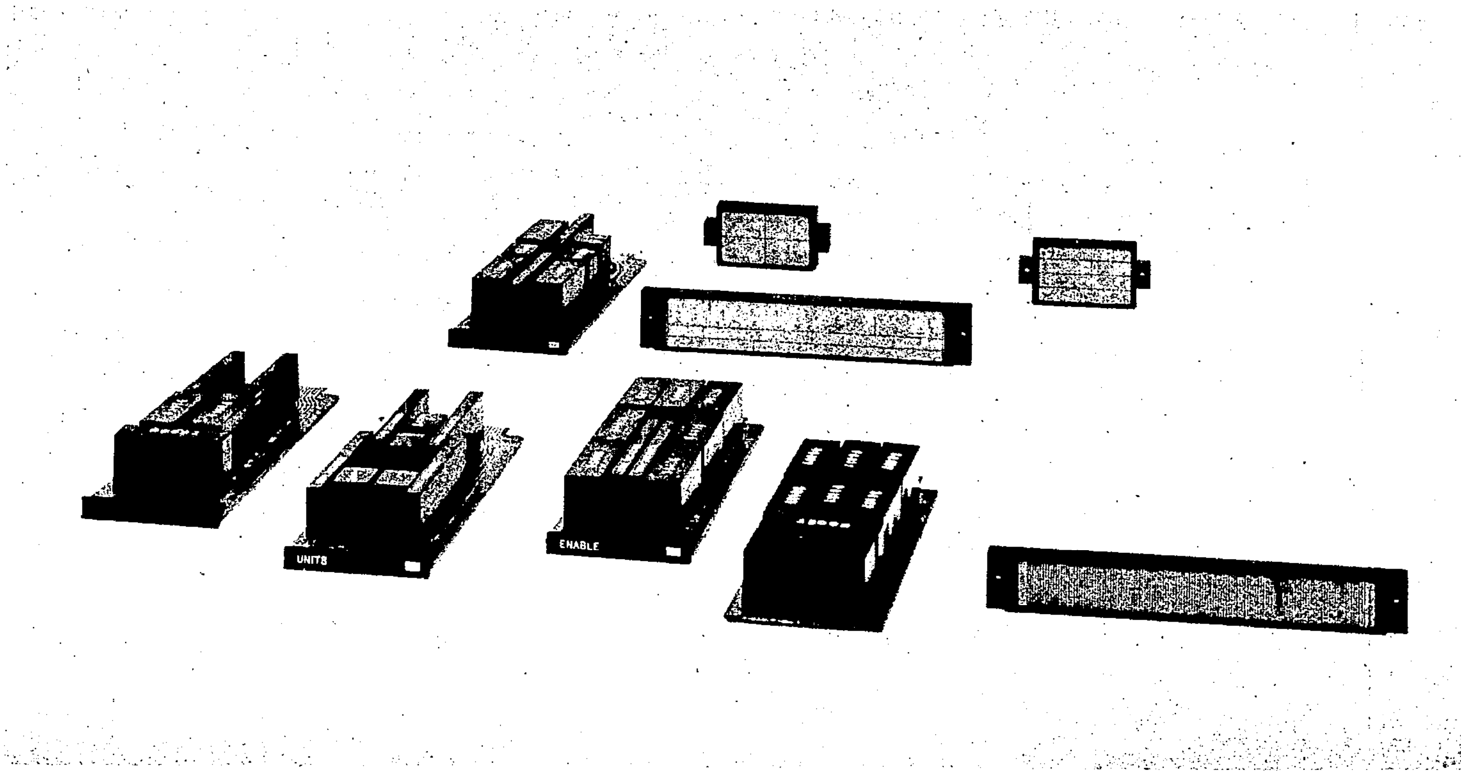
Enough parts are included in the above list of equipment and spares to construct either four (4) Single Parameter Units or two (2) Flight Direction Units.

Appendix D



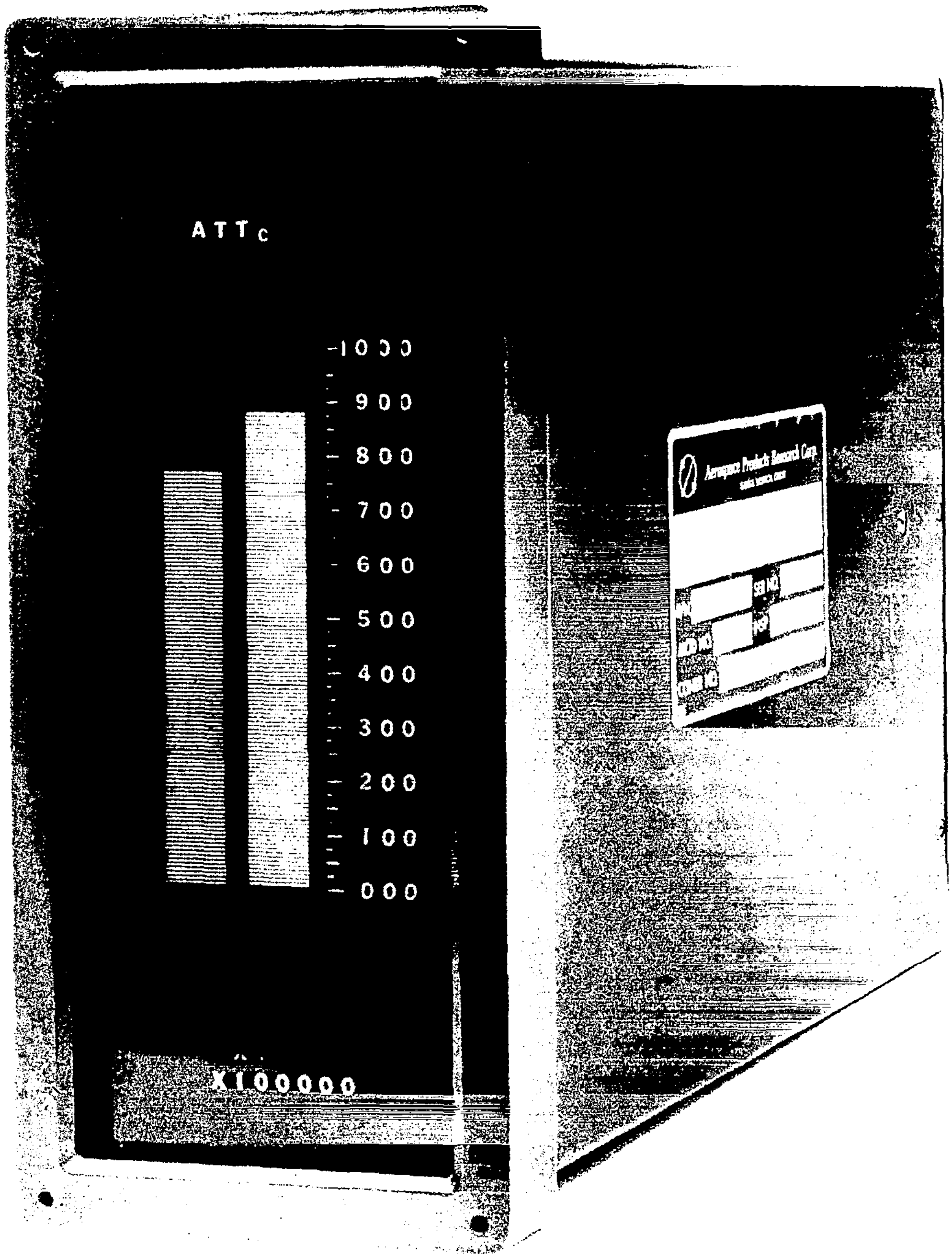
VERTICAL SCALE INDICATOR

Multi-mode digitally controlled electroluminescent bargraph-pointer

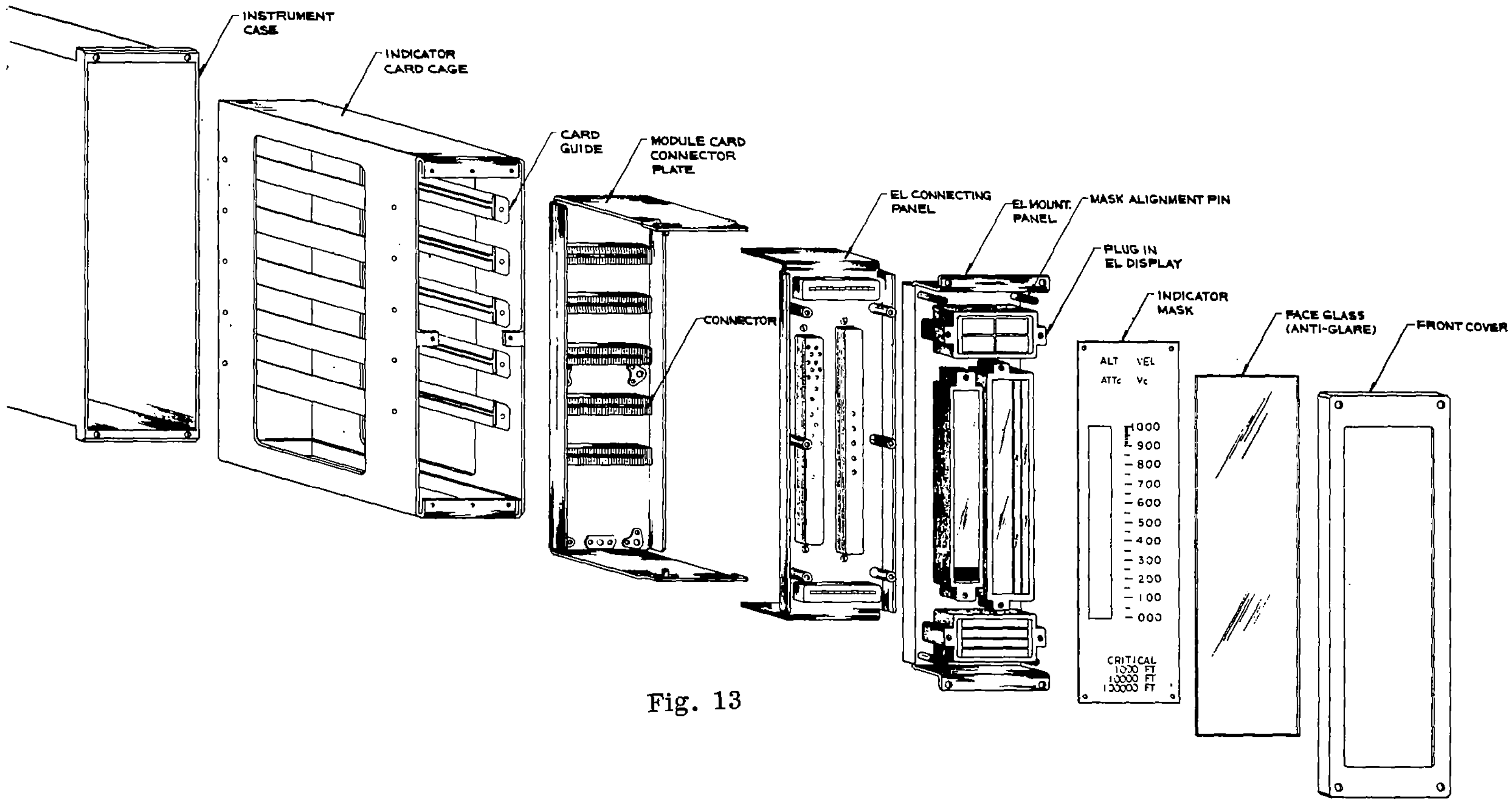


INDICATOR

Plug-In Lamps and Modules



FLIGHT DIRECTOR


INSTRUMENT CASE
INDICATOR CARD CAGE
CARD GUIDE
MODULE CARD CONNECTOR PLATE
CONNECTOR
EL CONNECTING PANEL
EL MOUNT. PANEL
MASK ALIGNMENT PIN
PLUG IN EL DISPLAY
INDICATOR MASK
FACE GLASS (ANTI-GLARE)
FRONT COVER
ALT VEL
ATTc Vc
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CRITICAL
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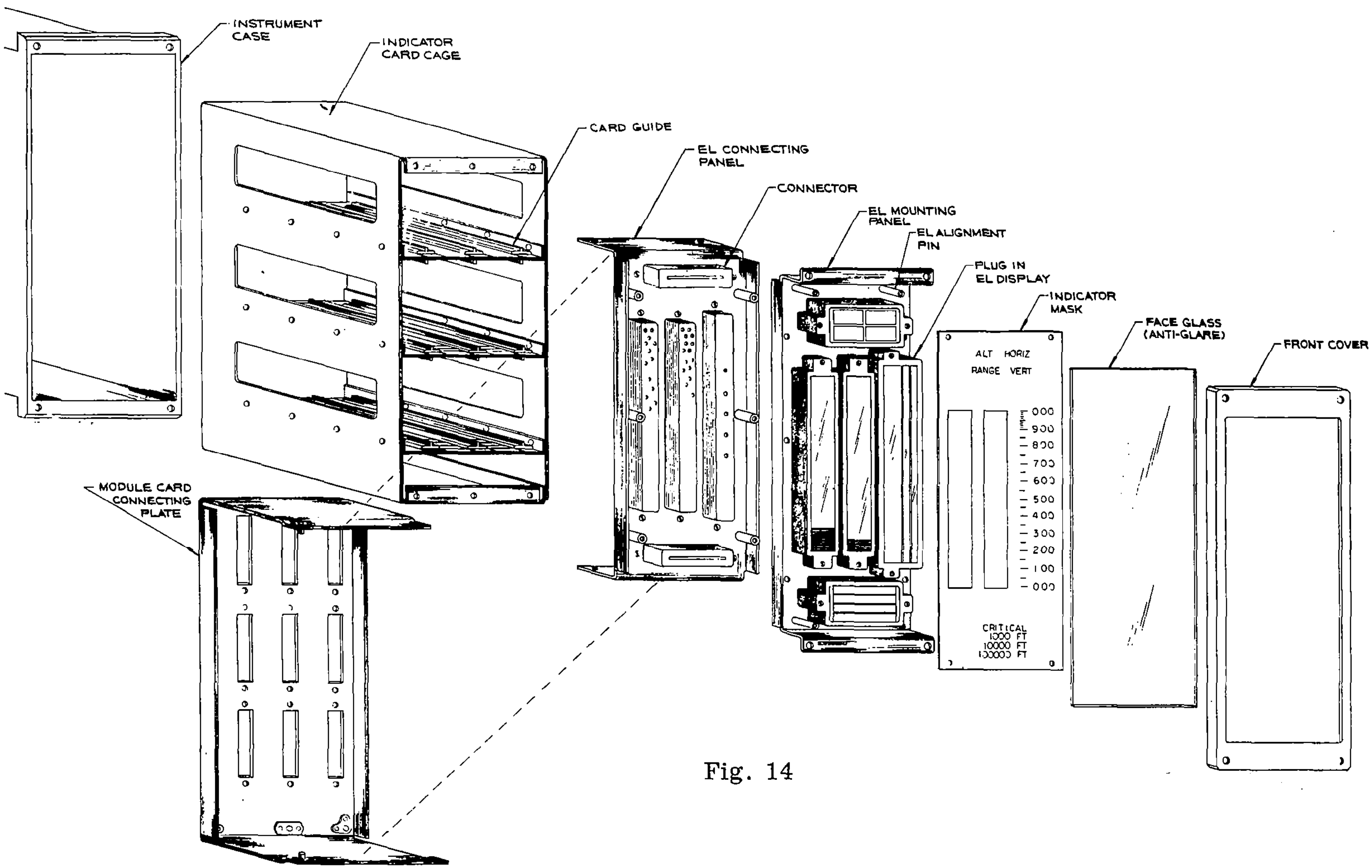
Fig. 13


INSTRUMENT CASE
INDICATOR CARD CAGE
CARD GUIDE
EL CONNECTING PANEL
CONNECTOR
EL MOUNTING PANEL
EL ALIGNMENT PIN
PLUG IN EL DISPLAY
INDICATOR MASK
FACE GLASS (ANTI-GLARE)
FRONT COVER
MODULE CARD CONNECTING PLATE
ALT HORIZ
RANGE VERT
000
900
800
700
600
500
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200
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CRITICAL
1000 FT
10000 FT
100000 FT

Fig. 14

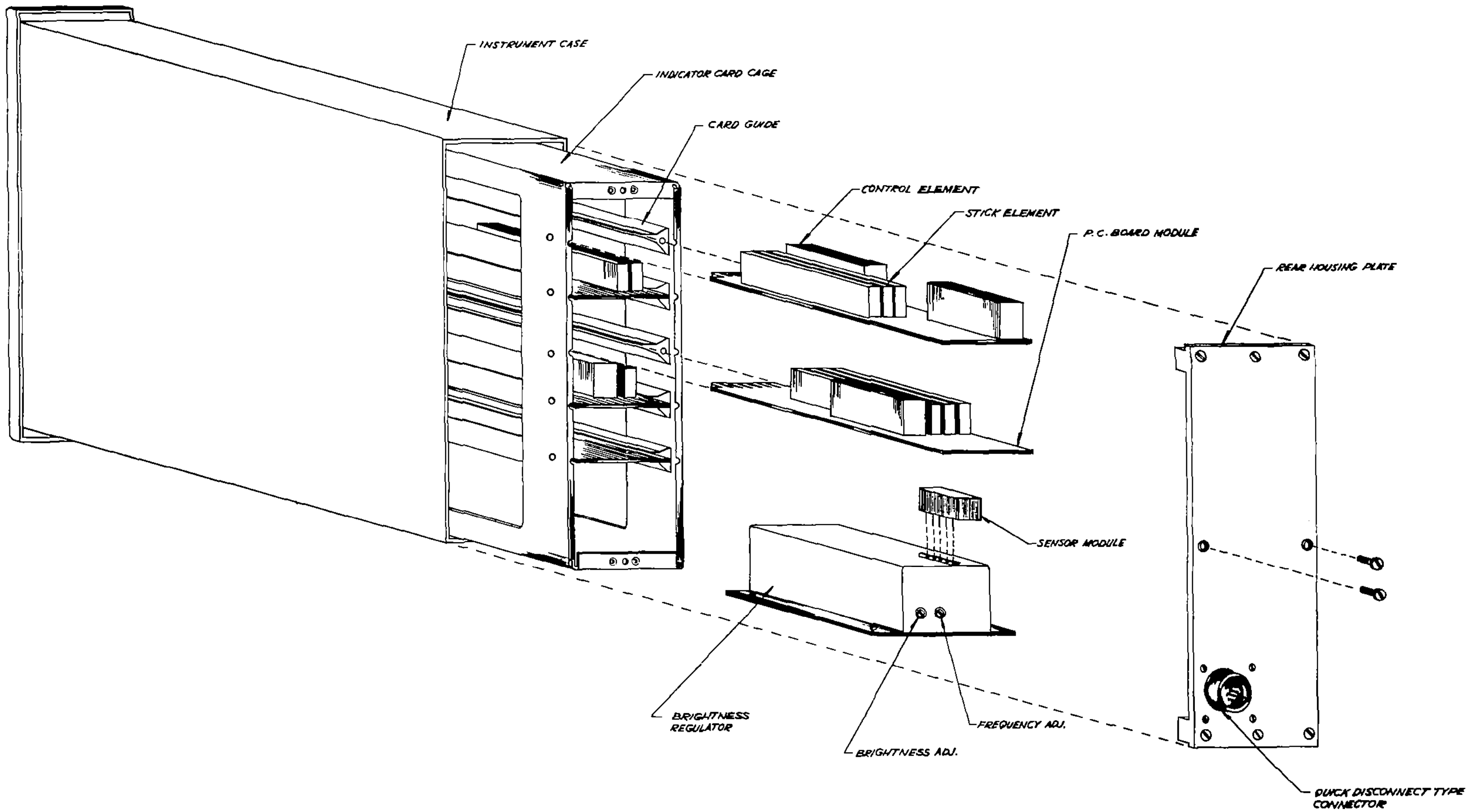
INSTRUMENT CASE
INDICATOR CARD CAGE
CARD GUIDE
CONTROL ELEMENT
STICK ELEMENT
P.C. BOARD MODULE
REAR HOUSING PLATE
SENSOR MODULE
BRIGHTNESS REGULATOR
FREQUENCY ADJ.
BRIGHTNESS ADJ.
QUICK DISCONNECT TYPE CONNECTOR

Fig. 15

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